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Contents

Artificial Fertilizers

Their Nature and Use

BY

B. LESLIE EMSLIE

P.C.S. F.R.S.I. C.D.A. (Glas.)

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"THE FARMER'S ADVOCATE"

ARTIFICIAL FERTILIZERS

Their Nature and Use

(SECOND EDITION)

By

B. LESLIE EMSLIE, F.C.S., P.A.S.I., C.D.A. (Glas.)

A series of articles which appeared in the columns of "The Farmer's Advocate" during February and March, 1908

To which is appended an article by the same author, on METHODS of HOME-MIXING and APPLYING FERTILIZERS from "The Farmer's Advocate" of 17th March, 1910.

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Artificial Fertilizers: Their Nature and Use

Introduction to the Second Edition

THE first edition of "Artificial Fertilizers: Their Nature and Use," which originally appeared as a series of articles in the columns of "The Farmers' Advocate" in the spring of 1908, met with such acceptance as a simple and comprehensive treatise on the use of commercial fertilizers, that it was decided to issue a second edition, substantiated with an additional article on "Methods of Home-Mixing and Applying Artificial Fertilizers" from "The Farmers' Advocate" of the 17th March, 1910. The inclusion of the latter article in this edition enhances its value, making it a more complete guide to the use of fertilizers, as the methods of mixing and applying these are treated in considerable detail.

Since the publication of the first edition, two years ago, some progress has been made in the field of fertilizer chemistry, especially in that branch of the science which deals with the Nitrogen problem.

The chief source of Nitrogen at the present time is Nitrate of Soda which is obtained from saline deposits on the Chilian coast in South America, but these deposits may not always suffice to supply the growing demand for the material. Partly for this reason, but chiefly because Nitrogen is by far the most expensive fertilizer ingredient, many prominent chemists have applied themselves to devising other

means of supplying this important element. We know that the atmosphere surrounding us contains, besides oxygen and traces of other gases, about 78% of free Nitrogen, which, however, is only available to one order of plants, the Legumes, to which belong Clover, Alfalfa, Beans, Peas and Vetches. It has lately been claimed that other plants besides the Legumes can assimilate the free Nitrogen of the atmosphere. While some may do so to a very small extent, we have no proof that they can abstract appreciable quantities. European chemists, therefore, directed their attention to the air supply of Nitrogen, and by an electrical process induced the atmospheric Nitrogen to combine with Lime and Carbon to form a Cyanamid of Lime, known also as "Lime Nitrogen" or "Kalk-Stickstoff." This substance is discussed in another part of the book. Within the last two years another electrical process for extracting atmospheric Nitrogen was devised by Berkeland in Norway, the product being Nitrate of Lime, containing 13% of Nitrogen. This substance is now being manufactured on a commercial scale, and in experiments, conducted at Rothamsted and elsewhere, has proved equal in value to Nitrate of Soda as a source of Nitrogen. As the latter, however, contains about 15½% of Nitrogen, as against 13% in the Nitrate of Lime, it would require 120 lbs. Nitrate of Lime to equal 100 lbs. Nitrate of Soda. The new fertilizer is not yet on our market and therefore need not at present receive further consideration here.

The Articles which comprised the first Edition of this book remain unaltered in the present, as no change was considered necessary, except in amplifying the contents by the appended article on mixing and applying fertilizers.

Without further comment, therefore, we submit the second edition to the reader in the hope that it will prove a simple and reliable guide to the proper understanding of the fundamental principles and application of Commercial Fertilizers.

B. L. E.

ARTIFICIAL FERTILIZERS:

THEIR NATURE AND USE

Article No. I.

The question as to whether it pays to use artificial fertilizers in Canada is being answered in very tangible form by the rapid increase in their consumption of late years, and there can be no doubt that this rate of increase will be more than maintained for years to come. The use of fertilizers in Canada has been permanently adopted, just as some 50 years ago in Europe and 25 years ago in the United States, artificial fertilizers came to stay, despite the fact that then, as now, many otherwise apparently reasonable and intelligent men condemned their use. But then, nothing of universal importance was ever introduced without receiving severe and adverse criticism; no measure for the advancement of the welfare of any community was ever adopted without it, so it is not to be expected that anything affecting the prosperity of the large agricultural populace of any land will be allowed to go unchallenged.

CAUSES OF PREJUDICE.

The prejudice which some may entertain against artificial fertilizers has, in many cases, arisen through failure to obtain the desired results from their use, which failure is, in the majority of cases, due to an insufficient knowledge of the nature and functions of the various fertilizing ingredients. It is essential that the farmer know something of what constitutes the fertility of a soil in order to properly understand the use of artificial fertilizers.

That there may be other causes of prejudice suggests to my mind an incident, related in a well-

known book in my "mither tongue," of two farmers going to kirk one Sabbath morning, and, taking a "short-cut" through a neighbor's farm, discovered some "manure in bags," which their neighbor had got to apply to his turnip land. Never having seen "Guano" before, they became deeply interested, and closely examined the wonderful stuff. One of them, surnamed Peter, not anticipating the consequences of his rash act, placed a handful of the Guano in his pocket for future reference, and the two hurried off to church, where they arrived rather late, and took their places beside their respective spouses, who had arrived some time previously in a wheeled conveyance.

Now, Guano, unlike the more popular concentrated fertilizers of to-day, has a very strong and decided odor, and the sample in Peter's pocket, being true to kind, emitted a stench which pervaded the whole building, seriously interrupting the attempt at devotion on the part of the worshippers.

Peter's better half, being ready at any time to lay blame on her husband for any misfortune, of which he was, of course, not always guilty, was not kept long in doubt as to the origin of the disturbance, and, on arriving home, her righteous indignation had full sway in the most awful curtain lecture which Peter ever endured.

As Mrs. Peter held the purse-strings, it is unlikely that her spouse ever summoned up courage enough to suggest the purchase of some Guano for the farm, and, to those without "inside information," he would naturally have been known as "prejudiced."

Well, as already mentioned, in order to use fertilizers intelligently, one must have some knowledge of what constitutes the fertility of a soil.

THE ELEMENTS OF FERTILITY.

Now, the farmer's object is to make his soil grow plants of various kinds, and the substances entering into the composition of the plant will indicate approxi-

mately what substances must be present in a "fertile" soil. If we take any living plant and reduce it to its elements, we find only a small range of substances. Water forms the greatest portion of the plant; the rest is almost wholly composed of compounds of carbon, with hydrogen and oxygen.

Nitrogen constitutes, on an average, about 2 per cent of the dry matter; the others, which are found in the ash when the plant is burnt, make up a further 2 per cent.

The ash constituents comprise potassium, sodium, calcium, magnesium, phosphorus, sulphur, silicon, chlorine, and a little iron and manganese. Traces of other substances occasionally occur in the ash of plants growing on soils which happen to contain them, but they are not essential.

Carbon is the chief element in the plant's composition, and this is obtained from the carbonic-acid gas in the atmosphere by means of specialized cells in the leaves of the plants. With the exception of nitrogen, potassium (or potash), phosphorus (or phosphoric acid) and calcium (or lime), the average soil contains sufficient amounts of plant-food substances for crop requirements.

The four essentials mentioned, however, of which the soil becomes depleted in the ordinary process of cropping, must be returned to the soil in some form if the fertility of that soil is to be maintained. The value of a fertilizer, therefore, must be assessed on the amounts of nitrogen, phosphoric acid, potash, and (in some cases, also) lime, which it contains.

Here it may be mentioned that lime is only in a very small measure a direct plant food, its chief virtue lying in the fact that it has a beneficial influence in counteracting the harmful effect of an excess of vegetable acids in the soil, and also to some extent in liberating plant-food substances.

Every pound of butter, every bushel of grain, every hundredweight of beef, pork or mutton, and every ton of hay, sold off the farm removes so much

fertilizing material, and, unless the latter be returned to the soil in some form, the soil will ultimately become exhausted and barren.

COMPOSITION OF STABLE MANURE.

In ordinary farm practice, the stable manure produced on the farm is applied to the soil, and by this means some fertilizing material is restored. One ton of stable manure may contain, on an average, 12 pounds nitrogen, 12 pounds potash, and 7 pounds phosphoric acid, or as much nitrogen as is contained in 75 pounds of nitrate of soda, as much potash as is contained in 24 pounds of muriate of potash, and as much phosphoric acid as is contained in 40 pounds acid phosphate. Since the most valuable part of the fertilizing ingredients of the manure is in the liquid portion, great loss is certain to occur through leaching, so that in the end the stable manure contains a small percentage indeed of fertilizing matter.

Perhaps the greatest value of stable manure lies in its physical action, whereby a stiff clay soil is rendered more open and porous, and a light, sandy soil is bound together thereby, and made more retentive of moisture. Besides this action farmyard manure provides the soil with humus, and furnishes a feeding-ground for the valuable bacteria.

SPECIAL DEMANDS OF CERTAIN CROPS.

Some people may contend that, where a large supply of farmyard manure is available, it is unnecessary to apply artificial fertilizers, but this argument doesn't always apply. Take, for example, the turnip crop, the success of which depends so much on a large, readily-available supply of phosphoric acid; to apply the required quantity of farmyard manure, supplying the necessary amount of phosphoric acid, would incur a great waste of nitrogen, the latter ingredient being much in excess of the needs of the crop. It is quite evident, then, that the most economical practice will

be to apply a light dressing of stable manure, balancing the same with some artificial fertilizer containing phosphoric acid and potash, and the extra stable manure could be profitably applied on another part of the farm.

ONE ELEMENT CANNOT SUBSTITUTE ANOTHER.

The most important fact for the farmer to know and remember in connection with artificial fertilizers is, that one ingredient cannot replace another, and to ignorance of this fact is due almost all cases of failure to get profitable returns.

To many farmers in Canada to-day, all fertilizers, be they nitrogenous, phosphatic or potassic, are simply known as "phosphates," for the reason that phosphatic fertilizers were the first introduced, just as in Scotland any kind of fertilizer was known as "Guano," because the latter was one of the first forms of commercial fertilizer which came into use there.

Bear in mind Liebig's "Law of Minimum," viz., "The substance in minimum rules the crop," which means that the plant-food substance present in the soil in smallest quantity will determine the amount of crop which can be grown on that soil. For instance, if the soil be deficient in either one of the three essentials (nitrogen, potash, or phosphoric acid), then, no matter how much of the other two ingredients were applied, maximum yields could not be obtained, since this is only possible when the plant's appetite for each essential has been satisfied. Another way of expressing the above-mentioned law is, "The strength of a chain is that of its weakest link."

If a farmer wishes to fatten a bullock, he does not reason thus: "Well, straw is cheap, and water doesn't cost anything; I'll give the bullock all the straw he can eat and all the water he can drink until he is fat." No, the feeder knows that straw and water do not

contain all the essential elements required to fatten a bullock; although straw or hay is a valuable part of the diet, he knows that other materials are necessary in order to produce a fat bullock. Then, why does not he exercise the same judgment in the case of his plants, for the same law holds good in both the plant and animal kingdom?

As one kind of animal differs from another in respect to its requirements and uses of the different elements of nutrition, so one kind of plant differs from another in its demands upon the various fertilizer ingredients in the soil. The benefits of a crop rotation are due to the fact that different crops have different requirements, e.g., a crop of clover will chiefly depend on its available supply of phosphoric acid and potash, but has no difficulty in obtaining its nitrogen, since the clover belongs to an order of plants (Leguminosæ) which can assimilate the free nitrogen of the atmosphere with the aid of certain bacteria living in little nodules on their roots.

Clover, then, not only secures all the nitrogen necessary for its own growth, but leaves in the soil, in the remains of its deeply-ramifying roots, a valuable stock of organic nitrogen for the next crop.

Now, wheat is a crop which greatly depends for its success on a large supply of nitrogen, so the clover crop is obviously a desirable predecessor for wheat.

Turnips seem to have most difficulty in getting their phosphoric acid, and, therefore, respond readily to an application of phosphoric acid in an easily-available form, such as acid phosphate (superphosphate).

Of course, some nitrogen and potash ought, also, as a rule, to be applied, but phosphoric acid is the dominant ingredient in a fertilizer for turnips. Potash is an important ingredient of a fertilizer for all crops, especially for clover, peas, beans and root crops, and is the dominant essential in a fertilizer for potatoes, tobaccos, etc.

SPECIAL NEEDS OF VARIOUS SOILS.

The character of the soil is a very important factor in determining the proportions of nitrogen, potash and phosphoric acid which a fertilizer intended for application to a certain crop on that soil shall contain.

A light, sandy soil will naturally be poor in all elements of fertility, and especially poor in potash. On the other hand, a clay soil will be naturally comparatively rich in potash, although the latter is frequently largely present in unavailable forms.

A peaty or swampy soil will be rich in nitrogen and poor in potash, lime and phosphoric acid. On such soils, basic slag, as a source of phosphoric acid, in conjunction with a potash fertilizer, has given very good results, on account of the free lime which the slag contains destroying the harmful effect of the vegetable acids naturally present in such soils.

SUMMARY.

If the reader has been able to follow these reasonings clearly, he will know:

That plants, as well as animals, require a variety of substances for their proper nourishment and growth.

That the ordinary soil contains a sufficiency of these for crop requirements, except nitrogen, potash, phosphoric acid and lime, of which the soil becomes depleted in the ordinary process of cropping.

That these substances are not interchangeable; one ingredient cannot replace another, but a complete fertilizer must contain proportions of all the essentials.

That the value of an artificial fertilizer, therefore, depends on the amounts of these substances which it contains.

That different kinds of crops have different requirements in respect to nitrogen, phosphoric acid, potash and lime, and that the various classes of soil differ in the amounts of these substances entering into their composition.

Article No. II.

In the previous article the writer endeavored to explain the fundamental principles of fertilizing, and in the present proposes to discuss the sources of the essential manurial ingredients, nitrogen, potash, phosphoric acid and lime.

FERTILIZERS EMPLOYED AS A SOURCE OF NITROGEN.

Nitrogen is the most expensive element in a fertilizer, and one of the most useful. The atmosphere contains about 78 per cent. of nitrogen, 21 per cent. of oxygen, a very small quantity of carbonic-acid gas (CO_2), and traces of other gaseous substances.

We have already seen that plants derive their supply of carbon from the carbonic-acid gas of the atmosphere, but the power of assimilating the valuable nitrogen, existing there in such abundant volume, seems to be limited to one special class of plants, known as Leguminosæ, including the clovers, peas, beans, alfalfa, etc.

It will be readily seen that a knowledge of this fact, viz., that there is at least one class of plant which can avail itself of the atmospheric nitrogen, is of paramount importance to the farmer. Its importance prohibits here the discussion which it merits, so we shall leave it till later on.

NITRATE OF SODA.

(contains 15½ to 16 per cent. nitrogen).

This is probably the best known and most popular source of nitrogen amongst farmers in Canada.

Its origin is the extensive deposits of crude nitrate of soda discovered in the rainless districts on the west coast of South America.

Since all nitrogenous compounds must first be converted into nitrates before being assimilated by plants, nitrate of soda contains its nitrogen in an easily assimilable form, and is, therefore, quick in action.

Owing to this fact, it almost invariably gives best results when applied in two or more applications, the first being given at the commencement of growth, and the succeeding ones at intervals of from two to three weeks.

This method not only provides the plants with a more regular supply of available nitrogen, but also prevents loss of this valuable substance by drainage, since nitrate nitrogen, unlike potash and phosphoric acid, is not firmly retained in the soil.

SULPHATE OF AMMONIA.

(contains about 20 per cent. nitrogen.)

The origin or source of this material is coal, which contains 1½ to 2 per cent. of nitrogen. It is chiefly a by-product of gas works. It is slower in its action than nitrate of soda, since, in order to render the ammonia available to plants, it must first be converted into a nitrate, which process is performed by certain soil bacteria.

In a moist climate or in a wet season, sulphate of ammonia is often preferable to nitrate of soda.

LIME NITROGEN (Kalkstickstoff)

(contains about 22 per cent. nitrogen).

This new nitrogenous fertilizer is produced by combining the free nitrogen of the atmosphere with lime and carbon, by a process devised by Prof. Frank, Berlin, Germany.

The principle is this: Air is conducted over heated copper filings; the copper forms a compound with the oxygen of the air, and the nitrogen passes

on into an electric furnace containing lime and carbonaceous matters, when, at the high temperature, the nitrogen is induced to combine with the lime and carbon, to form the substance, known in Germany as "Kalkstickstoff."

In view of the possible exhaustion of the nitrate of soda deposits (which some claim to foresee) and the very limited production of sulphate of ammonia, kalkstickstoff may yet become of great commercial importance. It has, however, certain undesirable qualities not possessed by either nitrate of soda or sulphate of ammonia; and here the writer can speak from experience, having conducted experiments in Germany to test the efficacy of the new nitrogenous manure in comparison with nitrate of soda and sulphate of ammonia:

1. Kalkstickstoff is an exceedingly fine black powder, which character renders it difficult of application.

2. If mixed with other fertilizers, such as acid phosphate, the mixture rapidly generates a great heat and gases are given off, some nitrogen being lost as ammonia and oxides of nitrogen.

3. In storing, it must be very carefully protected from moisture for the above reason.

4. Being at first rather poisonous to plants, kalkstickstoff is totally unsuited for application to a growing crop, and should always be applied to the land at least two weeks before seeding.

If these precautions are observed, kalkstickstoff may give results equal to nitrate of soda and sulphate of ammonia on most crops and soils.

Some of the slower acting sources of nitrogen are.

RED DRIED BLOOD (containing 13 to 14 per cent. nitrogen).

BLACK DRIED BLOOD (containing 6 to 12 per cent. nitrogen).

HOOF MEAL (containing 12 per cent. nitrogen).

TANKAGE (containing 4 to 9 per cent. nitrogen).

CONCENTRATED TANKAGE (containing 10 to 12 per cent. nitrogen).

The above are all produced from slaughter-house refuse. As will be seen, the lower grades of these substances, viz., Black Dried Blood and Tankage (ordinary) are very variable in composition. They also contain varying percentages of phosphoric acid.

There are numerous other sources of nitrogen, such as the various fish manures, some of which are valuable, if they do not contain too much oil, which is detrimental to the soil, as it hinders decomposition.

Then there are others, such as leather meal, wool and hair waste, and horn meal. The nitrogen in these is, however, so slowly available that their value as fertilizers is small.

It is none the less necessary, however, that the farmer should know of these sources of nitrogen, as they are largely used in fertilizer mixtures, for, as already mentioned, nitrogen is the most expensive ingredient in a fertilizer, and it is a great temptation to the less scrupulous fertilizer manufacturer to get his nitrogen from the cheapest source, and in a mixture it is difficult for a farmer to detect the various substances of which that mixture is composed.

FERTILIZERS EMPLOYED AS A SOURCE OF POTASH.

KAINIT (contains 12½ per cent. pure potash).

POTASH MANURE SALT (contains 20 per cent. pure potash).

MURIATE OF POTASH (contains 50 per cent. pure potash).

SULPHATE OF POTASH (contains 50 per cent. pure potash).

SULPHATE OF POTASH-MAGNESIA (contains 26 per cent. pure potash).

All these have their origin in the Stassfurt Potash Mines in Germany.

The Kainit is a crude potash salt, very largely used as a fertilizer in Europe, but, on account of its low potash content and high cost of transport, is less extensively used in Canada, the concentrated salts, Sulphate of Potash and Muriate of Potash,. being preferred. Muriate of Potash finds the largest sale, being rather cheaper than the sulphate, but, for tobacco, potatoes and sugar beets, Sulphate of Potash ought to be used, the chlorine content of the muriate sometimes having a detrimental effect on the quality of these crops. Especially is this true in the case of the tobacco crop, since the best-burning leaf is associated with a large percentage of potash and small chlorine content.

WOOD ASHES are largely used in some parts of Canada as a source of potash, but the total potash content is so small (about 5 per cent. on an average) and so variable that it is difficult to tell what one is purchasing.

The form in which the potash of wood ashes exists, viz., carbonate of potash, is very suitable, as in this form it is readily available to the plant. Some claim that wood ashes are apt to produce "scab" on potatoes, but as to the reliability of this assertion the writer canont vouch.

In extensive experiments conducted some years ago at Tokio, Japan, kainit, in every case, gave larger and more profitable returns than wood ashes

Article No. III.

FERTILIZERS USED AS SOURCES OF PHOSPHORIC ACID.

BONES.—The virtue of bones for manurial purposes was known to the Romans, so that they are one of the very oldest phosphatic fertilizers. Though no longer the only source of phosphoric acid, bones are still a very important factor in the fertilizer trade. They are sold chiefly in three forms: (1) After treatment with acid; (2) in the raw, ground-up condition, only the fat having been removed, as bone meal; and (3) after they have been degelatinized and the greater part of the nitrogen removed, as steamed bone flour.

BONE MEAL contains about 22 per cent. of phosphoric acid and 4 per cent. of nitrogen. This is a rather slow-acting form of phosphoric fertilizer, especially if the particles are large. Being an organic substance, its decomposition is facilitated by bacteria, but the process is necessarily slow.

STEAMED BONE FLOUR contains 28 to 30 per cent. phosphoric acid, and $1\frac{1}{4}$ to $1\frac{3}{4}$ per cent. nitrogen. This is a more useful form of phosphatic fertilizer than pure raw bone, since, in the steaming process, besides losing the fat (which is detrimental), it is reduced to a fine state of division, thus presenting a larger surface to bacteria and other agents of decomposition in the soil.

BONE BLACK.—Contains 32 to 36 per cent. phosphoric acid.

BONE ASH.—Contains 27 to 36 per cent. phosphoric acid.

The two latter are only produced to a limited extent. Bone Black is the residue of bones which have been used in clarifying sugar; it decays slowly in the

soil. Bone Ash results from burning bone, in order to reduce its bulk and thus facilitate transportation. It is more variable in composition than Bone Black.

MINERAL SOURCES OF PHOSPHORIC ACID.

In England, in 1845, the attention of agriculturists and fertilizer manufacturers was called to the coprolites which occurred over a considerable area of the eastern counties. These coprolites, which resemble pebbles in form and appearance, containing 50 to 60 per cent. calcium phosphate, consist of concretions of phosphate of lime deposited around excreta, fragments of bone and shell, sharks' teeth, etc., and were for many years mined in Bedfordshire, Cambridge, Suffolk, etc., though now it has entirely ceased, owing to the richer deposits which have been discovered in Florida, Tennessee, and South Carolina.

CANADIAN APATITE.—Contains about 40 per cent. phosphoric acid. This is mined to some extent in the Provinces of Quebec and Ontario, but, as it occurs in varying proportions with other materials, it is not uniform in character, and is very expensive to mine.

SUPERPHOSPHATE OR ACID PHOSPHATE.—Contains 13 to 18 per cent. available phosphoric acid.

Natural phosphate of lime is insoluble in water, and only slightly soluble in dilute acid, so that in this condition it would be very slowly available to plants. By treating the ground mineral phosphate with strong sulphuric acid, part of the lime is displaced and substituted by water, which renders a great part of the phosphate soluble in water, and therefore readily available to plants. The change may be illustrated thus:

Ordinary tri-calcic phosphate.............. $\left.\begin{array}{l}\text{Lime}\\ \text{Lime}\\ \text{Lime}\end{array}\right\}$ Phosphoric Acid.

Treated with sulphuric acid, produces:

Superphosphate or mono-calcic phosphate... $\left.\begin{array}{l}\text{Lime}\\ \text{Water}\\ \text{Water}\end{array}\right\}$ Phosphoric Acid.

When applied to the soil, superphosphate tends to revert again to the tri-calcic phosphate, but first of all to the di-calcic phosphate, which may be illustrated thus:

$$\left.\begin{array}{l}\text{Lime}\\ \text{Lime}\\ \text{Water}\end{array}\right\}\text{Phosphoric Acid,}$$

lime having displaced one part of the water. In this form it is still available to plants, being soluble in dilute acid.

Superphosphate, or acid phosphate, is deservedly one of the most popular sources of phosphoric acid for plants, its quick action giving immediate returns in the season of its application; this naturally recommends it to the farmer.

THOMAS' PHOSPHATE POWDER OR BASIC SLAG (High-Grade).—Contains 18 to 24 per cent. available phosphoric acid. This material is a by-product in the manufacture of steel. Its peculiarity is that it contains its phosphoric acid in the form of a tetra-calcic phosphate, or in the proportions of four parts of lime to one of phosphoric acid, thus:

$$\left.\begin{array}{l}\text{Lime}\\ \text{Lime}\\ \text{Lime}\\ \text{Lime}\end{array}\right\}\text{Phosphoric Acid.}$$

This peculiar form of phosphate of lime is easily broken up, rendering the phosphoric-acid part assimilable to plants, but it is not so quickly available as that in acid phosphate, so that, to secure the best results, basic slag ought to be applied in the fall or early in spring.

The chief value of basic slag depends on fineness of grinding, and a good sample ought to be so finely divided that not less than 80 per cent. will pass through a sieve having 10,000 meshes to the square inch.

CHEMICAL ANALYSES OF SOILS.

At one time it was thought that a chemical analysis of the soil ought to indicate exactly the manurial requirements of that particular soil, but this theory was very soon upset, when it was observed that certain rich clay soils, which on analysis showed a very high total potash contents, were still benefitted by an artificial application of potash, as proved by the increase in crop production.

Some soils, also, which analyzed high in phosphoric acid, were found to respond readily to an artificial application of an available phosphatic fertilizer.

Now, while a general chemical analysis will show the total amounts of plant food in the soil, it does not indicate what proportions are available to the plant, so that the quickest way to find out the manurial requirements of a soil is to conduct fertilizer tests on the farm.

PLAN FOR A FERTILIZER EXPERIMENT.

The following plan of experiment would show whether any ingredient may be profitably dispensed with, in the case of the particular crop on that particular soil:

Plot 1.—Unfertilized.

Plot 2.—Complete fertilizer (phosphoric acid, potash, nitrogen).

Plot 3.—Without potash (phosphoric acid, nitrogen).

Plot 4.—Without nitrogen (potash, phosphoric acid).

Plot 5.—Without phosphoric acid (potash, nitrogen).

The sources of phosphoric acid, potash and nitrogen used in the experiments may be any of those previously enumerated; for example, Acid Phosphate, Muriate of Potash, and Nitrate of Soda.

This plan of experiment may be extended or curtailed, as desired. If the farmer simply wishes to study the general effect of a complete fertilizer on his soil, then plots 1 and 2 will be sufficient; but should he desire to observe the effect of omitting any ingredient, he must have a third plot in which that ingredient is left out. To extend the plan, plots could be added to which each ingredient would be separately applied, but the average farmer will be content with the more simple tests, necessitating only two or three plots.

ADVANTAGES OF HOME MIXING OF FERTILIZERS.

When the Canadian farmer becomes sufficiently interested in the fertilizer question to want to make his own mixtures at home, it will be a good thing for the farmer and for the country in general. Then, fertilizers will be more largely and, at the same time, more economically used, for the farmer will be able to adjust the various fertilizer ingredients to suit not only the nature of the soil, but also of the crop to which they are to be applied.

He will be able to supplement his farmyard manure with some phosphate and potash without applying at the same time a wasteful excess of nitrogen, and, besides all this saving, the separate fertilizer ingredients will cost much less than when combined in a ready-mixed fertilizer.

Article No. IV.

IMPORTANCE OF LEGUMINOUS CROPS IN THE ROTATION.

As already observed, nitrogen is by far the most expensive plant food on the market. It has also been indicated that the natural order of plants known as Leguminosæ, to which belong the clovers, alfalfa, hairy vetch, beans, peas, etc., are peculiarly endowed with the power of extracting the nitrogen of the atmosphere by the aid of bacteria living in small nodules on their roots.

HELLRIEGEL'S DISCOVERY.

For this valuable discovery we are indebted to the famous German Agricultural Chemist, Hellriegel, of Bernburg, and his assistant and successor, the late Prof. Dr. Wilfarth.

Briefly stated, the discovery was in this wise: Plants of various kinds were grown in pots filled with pure sand, the sand being, of course, free of all traces of plant food. The plant nutrients were applied to the pots in solutions containing different quantities and proportions of the same, in order to ascertain the actual plant-food requirements of the plants. It was observed that legumes grown in pots which had received applications of phosphate and potash, but no nitrogen, continued to thrive, and ultimately yielded as well as the legumes in other pots which had received an application of nitrogen in the solution.

Furthermore, it was found that the soil in which the legumes had grown was finally far richer in nitrogen than at the commencement of the experiment.

Hellriegel naturally argued from this that the legumes have some means of obtaining their nitrogen

supply not possessed by other orders of plants. It had already been noticed that the roots of clovers and other legumes were usually covered with small tuberous growths or nodules, and to these Hellriegel directed his attention. He found that these nodules contained myriads of bacteria, and were exceedingly rich in nitrogen, and succeeded in establishing the fact beyond a doubt that these bacteria were instrumental in obtaining for the plant its supply of nitrogen.

A NITROGEN FACTORY IN THE SOIL.

The importance of this discovery to the whole world cannot be overestimated, for it indicated to the farmer a means by which he could establish a nitrogen-producing factory in his own soil—a factory which would actually "work while he slept." By growing a crop of clover, alfalfa, beans or peas, not only do these crops obtain the nitrogen necessary for their own development without any expense to the farmer, but leave in the soil, in the crop residue, a supply of nitrogen for the succeeding crop.

It is very obvious, then, that the introduction of a leguminous crop as frequently as possible in the rotation is an admirable policy.

CLOVER IN ANNAPOLIS VALLEY ORCHARDS.

This policy has for long been in force in many parts of Canada, and for one notable example we can point to the famous Annapolis Valley in Nova Scotia, where for years the fruit-growers have grown and plowed under clover crops in their orchards, thus supplying the soil with nitrogen and humus.

The only fertilizers which they apply are those containing phosphoric acid and potash, usually in the forms of bone meal and muriate of potash, which are applied annually at the rate of 400 to 600 pounds bone meal and 200 to 400 pounds muriate of potash per acre, the larger amounts being for orchards in full bearing.

The clover is usually seeded down in June, and occupies the ground until May of the following year, when it is ploughed under and the land thoroughly cultivated. Sometimes the clover crop is only grown once in every two years, which allows of the soil being more thoroughly cultivated and cleaned during the summer season.

CONSERVING THE MOISTURE IN SOILS.

Frequent stirring of the surface soil is very effective in conserving the moisture, as, when a soil is tightly packed, the water tends to rise to the surface and escape by evaporation. The breaking of the surface crust prevents this.

A COMPARISON OF VARIOUS LEGUMES.

COMMON RED CLOVER is unquestionably one of the best nitrogen-gatherers. An analysis of its stems and leaves shows a percentage of 0.92 nitrogen, and of its roots 0.88 per cent. nitrogen, and, as the weight of its roots is more than one-half that of its stems and leaves, quite an amount of nitrogen is stored up in the underground part of the plant.

MAMMOTH RED CLOVER, although a heavier yielder than the common red, contains a smaller percentage of nitrogen than the latter, so that, as a rule, a larger total amount of nitrogen per acre is left in the crop residue from common red clover.

CRIMSON CLOVER, as a fixer of nitrogen, is less desirable than the two former, since its root system is not nearly so extensive.

The same may be said of hairy vetch.

ALFALFA—The root system of this crop is very extensive, and penetrates to a great depth in the soil. The total weight of roots is, in fact, equal to that of stems and leaves, and the percentage of nitrogen in

both is similar, so that, while approximately one-third of the total nitrogen content of the clover crop is in the roots, one-half of the nitrogen of alfalfa is contained in the roots of the plant.

HOW TO STIMULATE PRODUCTION OF NITROGEN IN THE SOIL.

If the farmer grows a crop of clover or other leguminous crop, having in view the enrichment of the soil in nitrogen, he will naturally wish to have as big a crop as possible, and the way to insure the proper development of a nitrogen-gathering crop, so as to enable it to rob the atmosphere of the maximum quantity of valuable nitrogen, is to see that the crop is provided with a sufficient supply of the other plant foods, viz., phosphoric acid and potash. No factory can be kept going unless regularly supplied with the motive power necessary for the evolution of the finished product; no more can this nitrogen factory in the soil maintain its productive capacity unless a regular supply of power in the form of phosphoric acid and potash be available.

Legumes, although independent of an artificial source of nitrogen, are nevertheless very dependent on an easily-assimilable supply of the other plant foods.

A FERTILIZER FOR LEGUMES.

It might be well to give here a fertilizer prescription adaptable, under average conditions, to clover and alfalfa.

The following mixture might be found very profitable:

300 pounds Acid Phosphate.

120 pounds Muriate of Potash, per acre.

This would cost about $6.00.

In soils inclined to sourness, Basic Slag may be substituted for the Acid Phosphate.

For a mixture of clover and timothy hay, some artificial supply of nitrogen will, as a rule, be necessary to aid the timothy. If a medium dressing of barnyard manure be given, no further supply of nitrogenous fertilizer would be required, but in case of no barnyard manure being available, 75 pounds of Nitrate of Soda could be applied, in addition to the above quantities of phosphate and potash. The latter may be applied broadcast as early in spring as possible (especially if basic slag be the form of phosphate), since there is no danger of the potash and phosphoric acid being washed out of the soil; but, on account of its extreme solubility, and owing to the fact that it is readily leached out, Nitrate of Soda should not be applied until growth has commenced.

Article No. V.

Character of a Soil as Affecting its Fertilizer Requirements.

FORMATION OF SOILS.

Soil formation may be said to take place in two ways, either by a process of disintegration or breaking-down, or by a process of construction or building up. Both these processes of natural change are in constant operation, yet so slow and gradual in their advancement that their effects are almost imperceptible within the comparatively short span of a human life.

The physical character and chemical composition of a soil will naturally depend on the manner and origin of its formation. Soils formed by a process of disintegration will partake of the nature of the rock from which they were derived, and according to other conditions attendant on their formation. Others formed by a process of construction will likewise vary in character for similar reasons. In the latter class are included the alluvial deposits formed by the silt of rivers, etc., excellent illustrations of which may be found in the fertile Deltas, and the swamp and peat soils, which have been gradually built up through organic agencies, by the successive growth and decay of mosses and other simple forms of plant life.

EXHAUSTION OF SOIL FERTILITY.

The origin of a soil will then to a certain extent determine its fertilizer requirements, but the nature of the crop to be grown, as well as that of preceding crops, and previous treatment of the soil are also important determining factors. It must also be borne

in mind that the larger the crop grown the more fertilizing materials will be removed from the soil. However fertile the soil may be originally, continuous cropping is bound to exhaust it, unless measures are taken to restore the fertility.

Many farmers imagine that by occasional dressings of barnyard manure they are fully satisfying their debt of obligation to the soil for the substances which the soil has yielded up to the crops grown thereon, when an intelligent view of the matter would show them that while barnyard manure restores a small proportion of the fertilizing ingredients, the larger part has been permanently removed from the soil in the sale of produce from the farm, and in losses by evaporation and leaching from the manure itself. Other farmers acknowledge that barnyard manure alone is insufficient, but maintain that the growth of clover crops adds fertility to the soil. While this is very true with respect to the atmospheric nitrogen, which the clover plant assimilates and fixes, clover adds nothing to the soil's supply of potash and phosphoric acid. The growth of clover or any other crop will render some small portion of the soil's stock of phosphoric acid and potash available to the succeeding crop, but at the expense of the aggregate supply in the soil, and sooner or later the stock will give out.

The fact remains that resource must be had to artificial fertilizers if the requirements of the soil for all the elements of fertility are to be satisfied, and the sooner a farmer becomes cognizant of this, the less trouble will he have in restoring a runout soil.

Last fall the writer happened to be discussing the fertilizer question with a farmer, who owns a farm of a very light, sandy-loam character, when the latter made the remark that if it were not for artificial fertilizers, of which he uses large quantities annually, his land would not be worth farming.

The same day, in conversation with another farmer, he happened to inquire whether the farmer used artificial fertilizers, to which question the latter replied to the effect that there was too little money

to be made at farming to warrant its expenditure for fertilizers. Here are two different opinions, the one made by a man who had used fertilizers and proved their value, and the other by a man who knew nothing of the benefits to be derived from a judicious use of fertilizers, and who at the same time made the statement that farming was unprofitable.

RETURNS FROM MONEY INVESTED IN THE SOIL.

Many farmers would get higher interest on their money if deposited in the shape of fertilizers in the soil than if they placed it in the bank, the interest being paid in increased crops. The returns are surer than if the money were invested in a gold mine, yet how few seem ready to make the investment!

FORMS IN WHICH TO APPLY FERTILIZERS UNDER SPECIAL CONDITIONS.

Something has already been said in previous articles on the adaptability of certain forms of fertilizers to certain classes of crops and soils.

For instance, peat or swamp soil, containing naturally a large quantity of vegetable acids, ought not to receive fertilizers of an acid nature; hence, for such soils, basic slag as a source of phosphoric acid is preferable to acid phosphate, the free lime in the slag having a tendency to counteract the acidity of the soil. On soils inclined to excessive moistness sulphate of ammonia will be a more suitable form of nitrogen than nitrate of soda, on account of the sulphate of ammonia being less soluble and thus not easily leached out.

On peaty and swamp soils, or where a large amount of vegetable matter is present in the soil, very little or no artificial application of nitrogen will be necessary.

For potatoes, tobacco and sugar beets, potash ought to be applied in the form of sulphate of potash.

RULES TO BE OBSERVED IN PURCHASING ARTIFICIAL FERTILIZERS.

The purchaser ought always to demand a guarantee of the percentage contents of the various fertilizing ingredients in the fertilizer, as well as of the materials used as a source of the same. In nitrate of soda and sulphate of ammonia the nitrogen content will have to be guaranteed. In basic slag, of the total phosphoric acid, 80% ought to be soluble in citrate solution, and the sample should be of such fineness that 75% to 80% of it will pass through a sieve having 10,000 meshes per square inch. In superphosphate (acid phosphate) the water-soluble as well as citrate-soluble phosphoric acid will have to be guaranteed. The potash salts, both muriate and sulphate, contain 50% actual potash, and when purchased in the original sacks (225 lbs.), with lead seal attached, the purchaser may be confident that the goods are genuine.

Potash manure salt (containing 20% actual potash) has been in some cases sold by adventurers as sulphate of potash, hence the necessity of being assured as to percentage! Kainit contains 12.4% actual potash.

RULES TO BE OBSERVED IN MIXING FERTILIZERS.

Basic slag or quicklime ought never to be mixed with sulphate of ammonia, since the free lime of the former will combine with the sulphate part of the latter, and the valuable ammonia will escape as a gas. This loss is readily detected by the smell of the escaping ammonia.

A mixture of acid phosphate and nitrate of soda ought not to be stored for a long time in sacks, as the latter will rot away.

Acid phosphate may not be mixed with quicklime, since the lime by combining with the acid will render the phosphate less soluble.

The potash salts may be mixed with all other fertilizers, but a mixture of basic slag and either kainit or potash manure salt ought not to be kept over 24 hours, otherwise the mixture will become hard as cement.

RULES TO BE OBSERVED IN APPLYING FERTILIZERS.

1.—Bone meal and basic slag, on account of their comparatively slow action, often give better results if applied in the fall, so that their phosphoric acid will be more readily available in spring.

All phosphoric and potassic fertilizers may be applied in the fall or early spring without danger of serious loss by leaching, but nitrate of soda, on account of its great solubility, ought to be applied after growth has commenced.

2.—The fertilizers ought, as a rule, to be broadcasted either by hand or fertilizer distributor, being then lightly cultivated or harrowed in. It is not necessary to plow down fertilizers; they will find their way down readily enough.

3.—A one-sided fertilizer ought not to be given, but a fertilizer containing due proportions of all necessary ingredients, since phosphoric acid cannot replace potash, or *vice versa*.

4.—Sulphate of ammonia ought to be applied just before seeding, but nitrate of soda, as above indicated, ought to be given as a top dressing, and preferably in two or three applications.

5.—One must also remember that potash and phosphoric acid are firmly retained in the soil, whereas nitrogen is more or less readily lost. If, owing to

special weather conditions, the potash and phosphoric acid fail to act in one season, they will nevertheless prove effective during the succeeding one.

QUANTITIES OF FERTILIZERS FOR VARIOUS CROPS.

As already noticed, there are so many factors in determining the fertilizer requirements of a soil, that it is quite impossible to prescribe accurately the exact quantities to be applied, without a knowledge of the soil's condition, previous treatment, etc. However, it ought to be remembered that any excess of potash or phosphoric acid will be retained in the soil for the use of the succeeding crop.

The following prescriptions for some of the most important crops may be taken as approximating the requirements under average conditions. The smaller quantities may be applied along with a moderate dressing of barnyard manure, or where the soil is in a comparatively high state of fertility:

GRAIN CROPS.

Nitrogen..	75 to 120 lbs. nitrate of soda, or 50 to 100 lbs. sulphate of ammonia.
Phosphoric Acid...	200 to 300 lbs. acid phosphate, or 250 to 400 lbs. basic slag.
Potash....	75 to 120 lbs. muriate of potash, or 75 to 120 lbs. sulphate of potash.

POTATOES.

Nitrogen..	150 to 200 lbs. nitrate of soda, or 120 to 160 lbs. sulphate of ammonia.
Phosphoric Acid...	300 to 400 lbs. acid phosphate, or 350 to 500 lbs. basic slag.
Potash....	150 to 250 lbs. sulphate of potash, or 150 to 250 lbs. muriate of potash.

BEETS AND OTHER ROOT CROPS.

Nitrogen..	100 to 150 lbs. nitrate of soda, or 80 to 120 lbs. sulphate of ammonia.
Phosphoric Acid...	300 to 500 lbs. acid phosphate, or 350 to 600 lbs. basic slag.
Potash....	100 to 150 lbs. muriate of potash, or 100 to 150 lbs. sulphate of potash.

CORN.

Nitrogen..	100 to 150 lbs. nitrate of soda, or 80 to 120 lbs. sulphate of ammonia.
Phosphoric Acid...	300 to 400 lbs. acid phosphate, or 350 to 500 lbs. basic slag.
Potash....	100 to 150 lbs. muriate of potash, or 100 to 150 lbs. sulphate of potash.

ALFALFA, CLOVER, PEAS AND OTHER LEGUMES.

Nitrogen..	None necessary unless on very poor soil.
Phosphoric Acid...	250 to 400 lbs. acid phosphate, or 350 to 500 lbs. basic slag.
Potash....	125 to 175 lbs. muriate of potash, or 125 to 175 lbs. sulphate of potash.

PASTURES AND HAY.

Nitrogen..	100 to 200 lbs. nitrate of soda, or 80 to 160 lbs. sulphate of ammonia.
Phosphoric Acid...	250 to 350 lbs. acid phosphate, or 300 to 400 lbs. basic slag.
Potash....	80 to 150 lbs. muriate of potash, or 80 to 150 lbs. sulphate of potash.

CABBAGE AND OTHER SUCCULENT VEGETABLES.

Nitrogen..	250 to 400 lbs. nitrate of soda, or 200 to 350 lbs. sulphate of ammonia.
Phosphoric Acid...	400 to 600 lbs. acid phosphate, or 500 to 800 lbs. basic slag.
Potash....	150 to 250 lbs. muriate of potash, or 150 to 250 lbs. sulphate of potash.

FRUIT.

*Nitrogen.	75 to 150 lbs. nitrate of soda, or 60 to 120 lbs. sulphate of ammonia.
Phosphoric Acid...	300 to 500 lbs. acid phosphate, or 350 to 600 lbs. basic slag.
Potash....	200 to 300 lbs. muriate of potash, or 200 to 300 lbs. sulphate of potash.

TOBACCO.

Nitrogen..	150 to 250 lbs. nitrate of soda, or 120 to 200 lbs. sulphate of ammonia.
Phosphoric Acid...	250 to 400 lbs. acid phosphate, or 300 to 500 lbs. basic slag.
Potash....	160 to 320 lbs. sulphate of potash, or 320 to 640 lbs. sulphate of potash-magnesia.

**Where green manuring, or plowing under of a cover crop, is practiced as a means of supplying the valuable humus and nitrogen, very little or no artificial supply of nitrogen will be necessary.*

The writer trusts that in the scope of these articles he has succeeded in helping some to a clearer understanding of the nature and uses of commercial fertilizers, and that the knowledge gained will be turned to profit, for probably partly through this means will be ushered in the time when "the land shall yield her increase, and the desert shall blossom as the rose."

METHODS OF HOME-MIXING AND APPLYING FERTILIZERS

BY

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METHODS OF HOME-MIXING AND APPLYING FERTILIZERS

By B. Leslie Emslie.

As our farmers become more conversant with the principles of fertilizing there is naturally a growing tendency on their part to purchase the separate fertilizer ingredients and compound their own mixtures at home. Before discussing the methods employed in mixing and applying these materials, it might be well to briefly review the ARGUMENTS URGED FOR AND AGAINST THE HOME MIXING OF FERTILIZERS. We shall first take the arguments against the practice and, in our opinion, they are easily disposed of.

It is contended that:

1. The average farmer does not know enough about the nature of fertilizers to enable him to intelligently do his own mixing.

2. The manufacturer has facilities (machinery, etc.) for thoroughly mixing the materials which are not available to the farmer at home.

The first argument, however applicable it might have been 50 years ago, would be a reflection on the intelligence of the present-day Canadian farmer, when farming, in all its branches, has really become a science. Of course, it must be borne in mind that the use of commercial fertilizers in Canada is yet in its infancy, and probably most farmers in first essaying their use, employ some brand of ready-mixed fertilizer, but it speaks well for the discernment of our farmers that they soon turn their attention to the separate ingredients. Abundant proof of this may be found in the Maritime Provinces of the Dominion, whose farmers and orchardists are our pioneers in the

use of fertilizers and employ the separate ingredients almost exclusively.

The second argument has likewise no very substantial support, since in our experience no very great difficulty was ever encountered in getting a sufficiently fine and thorough mixture with the aid of the simple apparatus usually to be found on the farm.

ARGUMENTS IN FAVOR OF HOME MIXING.

1. ECONOMY: Usually at least 25% is saved in purchasing the separate ingredients. There is no useless "Filler" to add to the freight charges; there is no duty on the separate ingredients, whereas the farmer must bear the cost of the duty imposed on the ready-mixed fertilizers when these are imported from the United States.

2. ASSURANCE: The farmer who purchases the separate ingredients, especially if he insists on getting the goods in the original sacks, knows exactly what he is getting for his money; whereas the purchase of a ready-mixed brand is more often like buying a "pig in a sack."

3. ADAPTATION: With a stock of the separate ingredients on hand, the farmer is enabled to make up his mixtures according to prescriptions which he has prepared to suit the varying requirements of the different crops and soils.

From this short resumé each farmer may judge whether, in his case, it will pay him to purchase the separate ingredients in preference to the ready-mixed goods.

We do not wish to be understood as condemning the use of every brand of mixed fertilizers, but would caution the farmer who, for some reason prefers to employ the ready-mixed materials, to purchase the same from a RELIABLE MANUFACTURER IN CANADA, thus avoidng the payment of duty on the

same. Let him only purchase high-grade brands, i.e., those showing the highest percentages of Nitrogen, Phosphoric Acid and Potash, in the analysis. In compliance with the requirements of the new Canadian Fertilizer Act, the guaranteed analysis of the fertilizer must be stencilled on the sack, or printed on a tag attached to the same, which tag also bears the number under which that particular fertilizer has been registered at Ottawa and by means of which it may be identified.

For the farmer's guidance, in purchasing ready-mixed fertilizers, he may obtain from the Inland Revenue Department at Ottawa a bulletin, No. 186, entitled "Fertilizers as Sold." In this bulletin are listed all fertilizers offered for sale in Canada and the guaranteed and actual analysis of each is shown.

MATERIALS USED IN COMPOUNDING FERTILIZER MIXTURES.

The following are some of the more popular sources of Nitrogen, Phosphoric Acid and Potash:

Nitrogen..	Nitrate of Soda (about 16% Nitrogen). Sulphate of Ammonia (about 20% Nitrogen). Dried Blood (about 12% Nitrogen).
Phosphoric Acid...	Acid Phosphate (about 15% available Phosphoric Acid). Bone Meal (about 22% available Phosphoric Acid). Basic Slag (about 20% available Phosphoric Acid).
Potash...	Muriate of Potash (at least 50% actual Potash). Sulphate of Potash (at least 48% actual Potash). Kainit (at least 12½% actual Potash).

HOW TO FILL A PRESCRIPTION.

Supposing it is desired to prepare a mixture containing approximately 3, 9 and 10% Nitrogen, Phosphoric Acid and Potash respectively, it could be obtained as follows:

400 lbs. Nitrate of Soda (16% Nitrogen)=64 lbs. Nitrogen.
1,200 lbs. Acid Phosphate (15% Phosphoric Acid)= 180 lbs. Phosphoric Acid.
400 lbs. Muriate of Potash (50% Potash)=200 lbs. Potash.

2,000 lbs.

64 lbs. in 2,000 lbs. total mixture= 3.2% Nitrogen.
180 lbs. in 2,000 lbs. total mixture= 9. % Phosphoric Acid.
200 lbs. in 2,000 lbs. total mixture=10. % Potash.

$$\text{Thus } \frac{\text{Lbs., of ingredient in mixture} \times 100}{\text{Divided by total weight of mixture}} = \text{percentage of that ingredient.}$$

METHODS OF MIXING FERTILIZERS.

Machinery for mixing fertilizers is rarely available on the farm, but the operation may be easily and simply carried out without elaborate preparations. THE APPARATUS REQUISITE FOR THE OPERATION are: (a) the fertilizers, (b) the mixing floor, (c) a shovel, (d) a broom, (e) a wooden post, to be used as a pulverizer, and (f) a weigh scale. In mixing large quantities, the latter may sometimes be dispensed with, if it be remembered that, in the original sacks, the weights of the materials are usually as follows:

Nitrate of Soda and Sulphate of Ammonia—200 lbs. to the sack.
Acid Phosphate and Bone Meal—200 lbs. to the sack.
Sulphate and Muriate of Potash (always)—225 lbs. to the sack.

As the weigh scale is usually to hand, however, it is well to employ it to check the weights.

THE MODUS OPERANDI is as follows:

The mixing may be done on a solid, level part of the barn floor, or, if a cement concrete floor is available, it would be preferable to the wooden one, since the shovelling and crushing could more easily be done thereon. One ton will usually be a sufficient quantity to manipulate at one time, to insure thorough mixing. Sweep the floor clean; empty part of the phosphatic fertilizer and spread it level on the floor; on this put part of the Potash, then the remainder of the Phosphate and of the Potash.

If the Nitrogen, either in the form of Nitrate of Soda or Sulphate of Ammonia, is to be mixed with the rest, empty it out by itself on the floor, and with the aid of the wooden post and the back of the shovel reduce the lumps, for both of these materials are apt to become caked in the sacks. When the material has been reduced to sufficient fineness, spread it over the heap. Then take the shovel and turn the heap, first to one side and then to the other. After doing this a couple of times, the whole heap may be put through a sieve, any lumps remaining on the sieve being thrown to one side and afterwards reduced and again added to the heap, which may then be again turned a couple of times. It is not always necessary to use the sieve, but it is usually a great aid to thorough mixing.

After completing the operation in this way, fill the material into the empty sacks and proceed with the next batch.

PRECAUTIONS NECESSARY IN MIXING.

Never mix Sulphate of Ammonia with Basic Slag or Quicklime, for the free lime contained in the latter materials will enter into chemical combination with the Sulphate part of the former, thus setting free the Ammonia as a gas.

Never mix Acid Phosphate with Quicklime, since the lime by combining with the available Phosphoric Acid will revert the latter to the insoluble form.

Never allow a mixture containing Nitrate of Soda and Acid Phosphate to remain for a very lengthened period in sacks or the latter will rot away.

The Potash Salts may be mixed with all other fertilizers, but a mixture of Basic Slag (Thomas' Phosphate Powder) with Kainit ought to be applied at once, as the mixture will soon become as hard as cement.

WHEN TO APPLY FERTILIZERS.

This will be determined by (a) the nature of the crop, (b) climatic conditions, and (c) the rate of availability of the fertilizer constituents.

NATURE OF THE CROP.—For Hay and Pasture: The fertilizers may be applied as soon as the frost is out of the ground, and indeed for most other crops the Phosphatic and Potassic fertilizers might be advantageously applied as soon as it is possible to get on the land. Where this is not convenient, however, the fertilizers may be applied for CEREAL AND HOED CROPS at seeding time.

For Fruit Trees and Bushes: The application of the Phosphatic and Potassic fertilizers may take place before the ground freezes in the fall, or as soon as the frost leaves the ground in the spring.

CLIMATIC CONDITIONS: In localities with a low rainfall the fertilizers ought to be applied as early as possible, in order that their plant food constituents may become available to the plants when the latter are ready to make use of them. In moist climates the fertilizers need not be applied so early, and such very soluble Nitrogenous materials as Nitrate of Soda should be used sparingly.

RATE OF AVAILABILITY: IN NITRATE OF SODA, SULPHATE OF AMMONIA AND DRIED

BLOOD, we have three nitrogenous fertilizers, placed in the order of the availability of their nitrogen. Dried Blood is the slowest acting form and is, therefore, better adapted for early application. Nitrate of Soda is exceedingly quick acting, and, therefore, ought not to be applied long before the crop is ready to assimilate its nitrogen. In its rate of action, Sulphate of Ammonia is intermediate between the two. It is often considered desirable in making up a complete mixture to put in certain proportions of two or more different nitrogenous fertilizers to insure a more gradual and continuous supply of nitrogen. The special virtue of Nitrate of Soda is due to the fact that it provides a readily available supply of nitrogen to the young plant at a time when nitrification in the soil is only commencing.

Likewise in ACID PHOSPHATE, BASIC SLAG AND BONE MEAL, we have three carriers of Phosphoric Acid, placed in order of their activity. Basic Slag and Bone Meal, being slower than Acid Phosphate in their action, may be expected to give best results if applied in the fall or very early in the Spring. For late Spring application Acid Phosphate is to be preferred, unless on soils containing an excess of acid, where Basic Slag would be expected to correct the sour condition.

BOTH SULPHATE AND MURIATE OF POTASH are moderately quick in their action and suitable for Spring application, although they lose nothing by being applied in the Fall; in fact, if applied at the latter season, their Potash would usually be more available for the Spring-sown crop.

KAINIT (A CRUDE POTASH SALT) has been found to give best results when applied in the fall.

METHODS OF APPLYING FERTILIZERS.

Fertilizers may either be applied by hand or by a machine. Some modern grain seeders, potato and corn

planters have an attachment for sowing fertilizers, and there are now some makes of broadcast fertilizer distributors on the market. Where large quantities of fertilizers have to be applied the machine is a great labor-saver, and by its use a more equal distribution is insured. Generally speaking, we prefer the broadcasting machine to the drill or to any of the other mechanical devices referred to.

BROADCASTING BY HAND is easily and simply performed. The sowing "hopper" or basket might be described as a crescent-shaped, canvas-covered frame, with waist and shoulder straps attached. Both hands are used in the operation, and to obtain the proper rhythmical motion it is important to note that the right arm is swung backwards from the hopper as the left foot advances, and vice versa. The length of the stride can be adjusted to the thickness of sowing desired. THE BREADTH OF CAST is usually about the width of four potato or turnip rows.

Preparatory to commencing operations, the fertilizer sacks are placed at convenient intervals in the field; two men, or a man and a boy, can perform the work, one man doing the sowing and the other man, or boy, carrying the fertilizer in a pail from the sack to the sower.

THE BROADCAST SOWING MACHINE manufactured by a Canadian firm is made in two widths, 6½ feet and 8 feet. The latter is the more convenient size, since in sowing on ridged land it will take four ordinary sized rows. The box of this machine has a steel bottom provided with adjustable openings, controlled by a simple lever near the seat in front. A revolving cylinder with steel blades forces the fertilizers through these openings, and the latter can be adjusted to sow from 500 lbs. to 2,000 lbs. per acre by means of the aforementioned lever.

BROADCASTING FERTILIZERS ON POTATO ROWS.—When the sets have been planted in the row a heavy log, about 9 feet in length, or long enough to take four rows, may be dragged by a horse over the

rows so as to slightly flatten them and partially cover the potato sets. The fertilizers are then sown and the rows closed.

BROADCASTING ON THE LEVEL, whether in field or orchard, is an equally simple operation. The fertilizers should be harrowed or worked into the ground with a cultivator, except on sod, where cultivation is unnecessary. In the latter case, however, it is usually possible to apply the fertilizers rather earlier than on cultivated land, and they will thus have a better chance to get washed into the soil by the Spring rains.

BROADCASTING VERSUS DRILLING.—For various reasons, which shall be stated, we generally prefer to broadcast fertilizers to sowing them in the drill or row, although the latter practice has something to recommend it, chiefly, however, in that it saves time by combining the two operations of seeding and fertilizing. Our arguments in favor of broadcasting may be presented thus:

1. Broadcasting insures a more thorough distribution of the fertilizers in the soil, encouraging a more extensive root development, which gives the plants a greater feeding area.

2. The crops succeeding that to which the fertilizers have been applied will grow and ripen more uniformly. Take the instance of a cereal crop following a corn crop, to which the fertilizers were applied in the rows or hills, and note the uneven growth; the old corn rows can as a rule be traced from end to end of the field.

3. Broadcasting prevents an excessive concentration of fertilizers directly under the young plant, which in many cases might have an injurious effect.

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